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# U.S. Navy Halon 1211 Replacement Plan Part IV — Halon 1211 Replacement Program Plan

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# **U.S. NAVY HALON 1211 REPLACEMENT PLAN**

## **Part IV – Halon 1211 Replacement Program Plan**

### **1.0 INTRODUCTION**

#### **1.1 Background**

The U.S. Navy currently uses five firefighting agents for suppressing fires on flight lines and flight decks: water, Aqueous Film Forming Foam (AFFF), Halon 1211, potassium bicarbonate (PKP) and carbon dioxide (CO<sub>2</sub>) [NATOPS, 1994]. While each of these agents is potentially effective for flammable liquids or other combustibles typically encountered on flight lines and flight decks, each has advantages or disadvantages for a particular application. AFFF and water are the primary agents while PKP, Halon 1211 and CO<sub>2</sub> are secondary agents used with the primary agent or alone. The secondary agent is used alone in those situations where the primary agent is not effective and cannot completely extinguish the fire. It is often used in combination with the primary agent when increased effectiveness is required. For example, while AFFF is very effective in fighting pool fires and providing cooling, it is limited in fighting three-dimensional and hidden, obstructed fires. The three secondary agents are better than AFFF in fighting three-dimensional fires and hidden fires but do not provide effective cooling or burnback protection.

An important distinction between the five agents is the potential for causing collateral damage or damage caused by the agent to hot metal surfaces, electronics or avionics. Halon 1211 is recognized as the agent that will cause the least collateral damage. While Halon 1211 and CO<sub>2</sub> may both be considered 'clean,' CO<sub>2</sub> may, in some extreme circumstances, cause collateral damage due to thermal shock or static discharge. In addition, Halon 1211 is significantly more effective than CO<sub>2</sub>. PKP and AFFF are not clean agents and may cause considerable collateral damage. For this reason, Halon 1211 has become the agent of choice in many aviation firefighting applications. The ability to reduce or eliminate collateral damage has been thought to be particularly important for engine fires and internal electrical fires. The aircraft may be placed back into service more quickly and at a lower cost when only Halon 1211 is used to extinguish the fire [Leonard et al., 1992].

Halon 1211 was not the first clean, halocarbon agent to be used for aviation firefighting. Chlorobromomethane (CB), also known as Halon 1011, was used by the U.S. Air Force (USAF) as a streaming agent as early as the 1970s for flight line firefighting. Halon 1011 demonstrated the ability to limit collateral damage; however, it had corrosion and toxicity properties that were less than ideal. In the late 1970s, the USAF sponsored testing of Halon 1211 as a replacement for Halon 1011 [Chambers, 1977]. Halon 1211 was shown to possess the same positive attribute in

limiting collateral damage but was much less toxic and corrosive than Halon 1011. The USAF sponsored work and the experience with Halon 1211 in Europe led to the recommendation to replace Halon 1011 in flight line extinguishers [Novotny et al., 1975]. Although no definitive literature source has been found that delineates how the 150 pound capacity was determined, there is a fair amount of anecdotal information available [Chambers, 1977; Burns, 1996; Huston, 1996; Darwin, 1996-1997].

## **1.2 Halon 1211 on Navy (Ground Based) Flight Line Applications**

The Navy began to incorporate Halon 1211 into flight line firefighting as early as 1977 when Twin Agent Units (TAUs) with AFFF and Halon 1211 were purchased to replace TAUs with PKP [Rout, 1996-1997; NAVFAC, 1996]. Soon after, Halon 1211, 150 pound, wheeled flight line extinguishers were purchased by the Navy and Air Force. The 150 pound units are intended to provide for initial attack of fires by maintenance and operations crews. Halon 1211 was also placed within crash Fire Rescue (CFR) vehicles such as the P-19. The decision to require 500 pounds of Halon 1211 on CFR vehicles appears to be based on what would fit in available space rather than determining a precise quantity required to meet a particular fire threat. Within military CFR vehicles, 500 pounds was found to fit in the space previously used by PKP [Darwin 1996-1997].

In 1982, the FAA performed tests to qualify Halon 1211 as an acceptable alternative to PKP as a secondary agent for flight line CFR operations. These tests proved that Halon 1211 performed adequately [Geyer, 1982] and was subsequently approved for use. The FAA also came across the same 500 pound requirement by a different route. It appears that the 500 pound criterion was derived from an analysis of how much agent could be carried by a standard  $\frac{3}{4}$  ton pickup truck [Wright, 1995]. Although not derived from an evaluation of agent required to meet a particular fire threat, the 500 pound value has become the de-facto standard.

The National Fire Protection Association (NFPA) published the "Standard for Aircraft Rescue and Firefighting Services at Airports" in 1988 [NFPA 403, 1988]. Minimum extinguishing agent quantities and discharge rates were provided for the primary and secondary agents based on the airport category. Halon 1211 and PKP were given a one to one parity with respect to both agent quantities and discharge rates. There does not appear to have been any specific tests performed or referenced in the NFPA committee decision [Darwin 1996-1997]. The latest, 1993, version of NFPA 403 provides the same requirements for PKP and Halon 1211 as the 1988 version [NFPA 403, 1993].

## **1.3 Halon 1211 on Flight Decks**

Halon 1211 found its way to the flight deck of U.S. Naval vessels in the mid-1980s as a result of the crash of an EA-6B aircraft on the USS NIMITZ [Carhart et al., 1987]. AFFF, PKP and Halon 1211 were evaluated against a standard debris pile fire developed by the Naval Research Laboratory (NRL) [Carhart et al, 1987; Leonard, et al. 1992] to simulate the fire threat

encountered on the USS NIMITZ, a pool fire with aircraft debris and running fuel (leak) fires. Based on the work performed by NRL, Halon 1211 was chosen as the secondary agent to AFFF for flight deck firefighting. The flight deck firefighting vehicle, the P-16, was retrofitted to provide 400 pounds of Halon 1211 in addition to the on-board AFFF. As with the flight line CFR vehicles, the decision to require 400 pounds of Halon 1211 appears to be based on the space available within the P-16 vehicle [Darwin 1996-1997].

#### **1.4 Environmental Issues**

During the same time period that the Navy was increasing its reliance on Halon 1211, the international environmental community was linking the use of chlorofluorocarbons (CFCs) and halons to the destruction of the stratospheric ozone layer. The first international agreement was the Vienna Convention for the Protection of the Ozone Layer, signed in 1985. The Vienna Convention requires signatories to take appropriate measures to comply with its provisions including all protocols in force to protect against human activities that modify the stratospheric ozone layer. The major protocol under the Vienna Convention is the Montreal Protocol on Substances that Deplete the Ozone Layer, signed in 1987. At present, there are 156 Parties to the Protocol. The Protocol has been amended twice; the first Amendments to the Protocol were enacted in 1990 during a meeting in London and are, hence, termed the London Amendments. In 1992, the Copenhagen Amendments were adopted. Under the Copenhagen Amendments, production of Halon 1211 ceased in the US (and the rest of the developed nations) on 1 January 1994.

In the US, the Protocol was ratified by the Senate in 1988. The status of the Protocol as an International Treaty means that it takes precedence over national law. For example, Title VI of the Clean Air Act Amendments of 1990 (CAAA) requires that the more stringent control measures listed within the CAAA or the Protocol must be followed; the Environmental Protection Agency (EPA) has the responsibility to administer the regulations to adjust the control measures to ensure, as a minimum, compliance with the Protocol.

#### **1.5 Halon 1211 Use and Availability**

As a consequence of the Montreal Protocol, the Navy and all other users of Halon 1211 must rely on, and share, the quantities of Halon 1211 currently in existence. Recent actions under the Montreal Protocol have been aimed at determining the quantities of halons required to meet fire protection needs versus the quantities available. Surpluses of Halon 1211 may be targeted for mandatory collection and destruction. These actions may serve to reduce further the long-term availability of Halon 1211.

Since 1993, the Department of Defense (DOD) has established a strategic reserve of Halon 1211 to supply the needs of the services in lieu of relying on production. The quantities of Halon 1211 purchased, in supply, and used were not tracked in the logistics system. Local

purchases at dozens of locations hampered efforts to get precise data. Best estimates were developed to determine the quantities of Halon 1211 required for the Reserve [DDLA, undated (circa 1994)]. The major source of Halon 1211 to support the field has been the Reserve since 1993. With this main source of Halon 1211, the ability of the logistics community to track Halon 1211 issued to the field has been significantly increased. In addition, other military activities, government agencies and industry have been performing research, development, test and evaluation (RDT&E) to develop and prove-out technologies to replace Halon 1211. Recent changes within the Montreal Protocol, technology developments and availability of additional Halon 1211 logistics data provide both the need and opportunity to re-evaluate the continued use of Halon 1211.

A project directed at evaluating the continued reliance on Halon 1211 for aviation firefighting was developed. The work covered in the entire effort will be performed and reported in four parts: (1) Halon 1211 Alternative Development Status [Carpenter, et al. 1997], (2) Halon 1211 Requirements Review [Verdonik et al., January 7, 1998], (3) Halon 1211 Mission Critical Reserve Evaluation [Verdonik et al., January 14, 1998], and (4) Halon 1211 Replacement Program Plan. The work covered in this report is for Part IV - Halon 1211 Replacement Program Plan.

## **2.0 OBJECTIVE**

The overall objective of this project is to provide a basic input for a detailed Halon 1211 Replacement Program Plan. The purpose of the program plan is to ensure that the Navy is adequately prepared to support aviation CFR operations on flight lines and flight decks through continued use of Halon 1211 and/or replacement technologies.

The objective for the work performed under Part IV - Halon 1211 Replacement Program Plan was to outline the plans necessary to replace the current Halon 1211 firefighting systems. The recommendations and plans were based on the results from the previous three efforts of this study.

## **3.0 APPROACH**

### **3.1 Drop-in Agent Approach**

Two different approaches may be used to perform the re-evaluation of continued Halon 1211 use in developing the Replacement Plan. The first approach starts with the premise that every application that currently uses Halon 1211 must continue to use a Halon 1211 like replacement with exact attributes and capabilities of Halon 1211. This is the so called 'drop-in' philosophy where the one new agent must work in all current Halon 1211 equipment without modification. The new drop-in agent would have all of the positive attributes of Halon 1211 but

would not have the negative environmental impacts. It essentially defines the requirement as Halon 1211. It defines the purpose as replacing Halon 1211 and sets all of the performance objectives at those equal to Halon 1211. This approach limits the ability to create significant advances in technologies. The lure of the drop-in approach is that if it is successful there will be limited logistical and cost impacts. The major disadvantage is that if it is unsuccessful Halon 1211 will be the only agent available to meet the firefighting need. It has not been successful to date, following 12 years of research and development. A Naval Studies Board empaneled to evaluate Halon 1301 replacements found that "It is unlikely that a drop-in replacement agent will be discovered that will exhibit all of the beneficial properties of Halon 1301 and not also exhibit a significant environmental impact"[National Academy of Sciences, 1997].

### **3.2 Systems Engineering Approach**

The second approach starts with the premise that each application that currently uses Halon 1211 can be defined by a series of firefighting and related requirements. Instead of assuming that the requirement is to replace Halon 1211, it places the need at performing the required firefighting. It requires understanding and defining the firefighting requirements for each application. This philosophy places the emphasis on the systems engineering required to meet the threat and not solely on the agent itself. Tests need to be developed that adequately measure the ability of the system to meet the documented requirement. It requires a better understanding of the operational and technical requirements. The major advantage is that a wider range of technologies can be explored. This approach will also lead to a better understanding of the science and engineering involved, and enhances the ability to develop significant advances in technology.

Several organizations have shown great success with the systems engineering approach in resolving Halon 1301 applications. The Navy has proved out inert gas generators in the V-22 and F/A-18E/F, and the Army has proved out HFC-227 (FM-200™) in the RAH-66 for engine nacelle fire protection. Carbon dioxide portables, water mist and dry chemicals are all replacing Halon 1301 in various applications. HFC-236 has been commercialized as a 1211 replacement while CO<sub>2</sub> and dry chemicals are being used extensively in the private sector as Halon 1211 "replacements." All of these successful alternatives would have been eliminated from consideration using the drop-in approach. Emphasis has been placed on the systems engineering approach in performing and reporting this work.

### **3.3 Assignment IV - Halon 1211 Replacement Program Plan**

The results from the three project efforts to date, i.e., Part I - Development of Halon 1211 Alternatives, Part II - Halon 1211 Requirements Review, and Part III - Halon 1211 Mission Critical Reserve Evaluation were used to develop the testing efforts required to evaluate the potential near- and mid-term system alternatives available to meet the aviation firefighting requirements [Carpenter et al., 1997; Verdonik et al. 7 January 1998, 14 January 1998]. The test

methodology based on the defined, operational requirements is applicable for evaluation of systems to replace the currently fielded Halon 1211 systems and for evaluation of future technologies.

#### **4.0 SUMMARY OF PREVIOUS PROJECT EFFORTS**

##### **4.1 Summary of Part I - Development of Halon 1211 Alternatives [Carpenter et al., 1997]**

The review of work to find an alternative to Halon 1211 fell into three general areas: (1) Research, Development, Test and Evaluation (RDT&E) performed by the USAF, (2) T&E performed by the FAA and other national aviation authorities, and (3) T&E performed by commercial industry. The RDT&E efforts from 1985 to the present have not resulted in the development of a suitable Halon 1211 alternative. Given the status of current efforts, it does not appear likely that this work will produce an agent or agents for near-term use.

HFC-227ea and HFC-236fa are similar to perfluorohexane, a primary candidate that was eliminated from consideration due to environmental restrictions. While both of these agents will not perform as well as Halon 1211 based on the cup burner test and may not perform quite as well as a streaming agent, it is possible that systems using these agents may perform well enough to meet the fire fighting requirements on the flight line and flight deck. Both agents are being commercialized in hand held extinguishers with adequate UL ratings to replace Halon 1211 extinguishers.

In order to evaluate the commercially available near-term agents, it is necessary to develop the operational requirements for the fire fighting systems suitable to replace the current Halon 1211 systems. Based on the operational requirements, test methods, procedures and parameters should be developed that will assess the ability of candidate systems to meet or exceed these requirements. The evaluation should be performed against strict pass/fail criteria that are related to one or more aspects of the operational requirements. Tests may also be developed to evaluate the candidates in scenarios that would be "nice-to-have" but not required, to assess their effectiveness and provide guidance to firefighters.

The development and documentation of operational requirements, appropriate tests, and strict assessment methods would allow for the evaluation of near-term and longer-term agents. This course of action would also make it easier to re-evaluate the fire threats, change tests and update assessment methods as circumstances and materiel change in the future.

#### **4.2 Summary of Part II - Halon 1211 Requirements Review [Verdonik et al. 7 January 1998]**

A review and analysis was performed of the NATOPS, historical development of Halon 1211 systems and efforts to develop Halon 1211 alternative systems to determine the operational requirements used to develop the current Halon 1211 systems. These analyses revealed that the current system capabilities are not based on specific, defined operational requirements.

In order to develop the operational requirements, Fire Incident Data from the Naval Safety Center were collected and analyzed to determine the types and frequencies of fire events. Two separate sets of data were reviewed: (1) Navy incidents covering the years 1977-1991 and USAF fire incidents covering the years 1981-1991, from a previous study [Leonard et al., 1992]; and (2) Navy, USMC, USAF and Army fire incidents covering Fiscal Years (FY) 1993-1995 for incidents reporting Halon 1211 use. The results of the analysis are summarized as follows.

The results indicate that four common flight line incidents are prevalent: engine fires, wheel/brake fires, electrical fires and fuel spill fires. The results on 'common' fire types are consistent with the expected fire types listed in the NATOPS [NATOPS, 1994]. While only a small percentage of the fires in the fire incident data were large based on the dollar loss data, the fire fighting requirement exists for large catastrophic events (i.e., USS NIMITZ fire) as described in the NATOPS. Halon 1211 was the predominant agent for aircraft fires, particularly small fires where the collateral damage concerns are the greatest. AFFF and water were the predominant agent for large fires where the concerns for collateral damage are smallest.

Analysis of the effectiveness of the Halon 1211 systems indicated that the operational requirements cannot be based solely on the reported quantities of agent used in the fire incident data. The analysis needs to incorporate the system effectiveness for each fire type. Any efforts to replace the current Halon 1211 systems should not center on the agent quantities but on the overall system capabilities. When considered separately, the system capabilities needed may be different for hand held extinguishers, flight line extinguishers and CFR vehicles used shore side and the hand held extinguishers, P-16/P-25 and TAU-2H, used shipboard. When considered together, these systems must meet all of the operational requirements.

Hand held extinguishers are mainly needed for small electrical and engine fires where the need to minimize collateral damage is high. Clean agent hand held extinguishers need to be effective against limited size Class A and Class B fires and be suitable for Class C fires. For shipboard use, hand helds need at least the same capabilities as shore side, but they may also need to have a greater effectiveness. When the P-25 replaces the P-16, hand held extinguishers will be the main source of a secondary agent on the flight deck and may become the only source of a secondary agent that minimizes collateral damage. In this case, hand helds may also be needed to provide 3-D capabilities for large catastrophic events.

The flight line extinguisher (i.e., 150 pound, wheeled Halon 1211 unit) is the predominant system used by shore side crew, maintenance personnel and CFR staff. In part, this may be due to their presence as the main system available on the flight line. Depending upon the results for hand held extinguishers, flight line extinguishers may be needed in small to medium size engine fires, e.g., wet starts, tail pipe fires and electrical fires that may also involve a Class B material. The need to limit collateral damage in these fires may also be high based upon the size of the fire (i.e., may need a clean agent). The flight line extinguishers are also needed to extinguish the smaller wheel/brake fires, to control the 'larger' wheel/brake fires until the wheel/brake assembly can be cooled, to extinguish small pool fires and to control larger pool fires until the fire department responds with AFFF.

On a systems basis, Halon 1211 is used infrequently from the CFR vehicle. This may be due to (1) size of fires, (2) types of fires, (3) effectiveness of the current flight line extinguisher and (4) availability of the CFR vehicle. A small part of this low frequency may be due to the removal of Halon 1211 from internal tanks of USAF CFR vehicles. Although the incident data may not indicate a high frequency of large catastrophic events, the need for a secondary agent with three-dimensional capabilities is a requirement based on past fire experience (i.e., USS NIMITZ). These worst case scenarios do not happen often, but the CFR responders must maintain the capability should the event ever occur. Hand helds and/or flight line extinguishers may be capable of meeting the entirety of the 3-D requirements for large catastrophic events. If the CFR vehicle needs increased 3-D capabilities, it does not appear that it must be a clean agent.

The requirements for the P-16/P-25 and TAU-2H have not historically been the same as for either the flight line extinguisher or the CFR vehicle. While the P-16/P-25 and TAU-2H may be needed to extinguish small pool fires and control larger pool fires, this capability is handled through AFFF. Unlike the flight line extinguisher, 2-D fire capabilities are not a direct requirement for the secondary agent within these systems. If hand helds are completely adequate for the small fires, the P-16/P-25 and TAU-2H do not need a clean agent. It is also possible that hand helds may be completely adequate in providing the 3-D agent requirements for catastrophic events. Depending upon the ability of hand helds to provide adequate capabilities for small fires and the 3-D agent for catastrophic events, the P-16/P-25 and TAU-2H may need (1) greater clean agent capabilities for engine and electrical components and/or (2) increased secondary agent capabilities for 3-D fires than provided by hand held extinguishers.

It must be noted that PKP has historically been excluded from the list of potential agents considered to minimize collateral damage. This has been based on the perception that the use of PKP requires extensive clean up of engines. No definitive information was found during this study to verify or reject this perception. It is recommended that a study be undertaken to evaluate the collateral damage of PKP. If PKP were found to meet the collateral damage requirements, PKP systems would likely meet the operational requirements for all fires types.

In order to evaluate the potential Halon 1211 alternative system, specific tests and pass/fail criteria need to be developed based on meeting the specific, defined operational

requirements. The tests need to be performed on a system basis recognizing there are differences between shore side and shipboard system requirements.

#### **4.3 Summary of Part III - Halon 1211 Mission Critical Reserve Evaluation [Verdonik et al., 14 January 1998]**

The normally tracked Halon 1211 data were not sufficient to calculate either the total quantity of Halon 1211 within the Navy/USMC (i.e., Bank) or the Halon 1211 usage rate. In order to develop the size of the Bank and the historical usage rate, the normally tracked Halon 1211 data were supplemented with one-time data calls and other available data. The total Navy Bank of Halon 1211 is estimated to be approximately 2,000,000 pounds.

- The Reserve contains approximately 23 percent (450,000 pounds) of the Bank,
- The installed base contains approximately 55 percent (1,100,000) of the Bank, and
- The local back-up/storage supplies contain the remaining 22 percent (440,000) of the Bank of Halon 1211.

The historical usage rate was estimated by two different methods. The usage rate based on the fire incident data was estimated to be approximately 35,000 pounds of Halon 1211 per year. The rate based on the Reserve shipments data was estimated to be approximately 113,500 pounds of Halon 1211 per year. Based on the status of Halon 1211 alternative systems, the historical peace-time usage rates are projected to apply for the foreseeable future. Therefore, the Reserve is projected to be adequate to supply peace-time quantities of Halon 1211 for approximately 4 to 13 years. The usage rate based on the fire incident data versus the usage rate based on the Reserve shipment data suggests that the majority of the current use of Halon 1211 may not be for fighting fires.

Two potential sources exist to increase the quantity of Halon 1211 above that currently contained in the Reserve. It is possible that one-half to two-thirds of the fielded flight line extinguishers are in excess of the NATOPS requirements. It is projected that an additional 4 to 13 years of supply could be obtained. It is also possible to use the local storage/back-up supply of Halon 1211 without replacing it. This would provide an additional 4 to 13 years of supply. If both of the above options are feasible, then the Bank of Halon 1211 is projected to be able to support Navy/USMC peace-time requirements for approximately 12 to 39 years.

The projections for the adequacy of the Reserve do not account for any additional usage of Halon 1211 that may result from increased combat operations. It is also important to note that while the supplies of Halon 1211 may be adequate for this period of time, recent actions under the Montreal Protocol may decrease the amount of time that it is considered 'acceptable' to continue to rely upon Halon 1211.

#### **4.4 Conclusions of Previous Project Efforts**

While the currently fielded Halon 1211 systems were not developed based on specific, defined operational requirements, they are generally the only systems available with a proven record. Other systems with a proven record, such as PKP, have been ruled out of consideration based on the perceived failure to meet collateral damage requirements. Currently, flight line and flight deck fire fighting must rely on Halon 1211 systems with a limited supply of Halon 1211 available. The estimate developed within this study indicates that the Navy Reserve of Halon 1211 may only be adequate for 4 to 13 years [Verdonik et al., 1998b]. While options may exist to extend this period of time, it was based only on peace-time uses. Increased combat operations may significantly increase Halon 1211 usage and serve to decrease the time the Reserve can support aviation fire fighting requirements. In addition, recent developments within the Montreal Protocol may reduce or eliminate the ability to continue to rely on the current quantities of Halon 1211 to meet the requirements.

In recognition of the limited quantity of Halon 1211 available, the uncertainties in combat requirements and future use restrictions and the time required to demonstrate, validate and field equipment, it does not appear prudent to continue to rely solely on Halon 1211 systems to meet aviation fire fighting needs. Alternative systems need to be identified that will be available in the near- and mid-term should the need arise to replace the current Halon 1211 systems. The only near- and mid-term agents and systems that have the potential to replace the current Halon 1211 aviation fire fighting systems are those that are either currently fielded, available commercially or may be developed based on commercially available agents. An effort is needed to evaluate these potential Halon 1211 alternative systems based on the specific, defined operational requirements developed within this study.

### **5.0 HALON 1211 ALTERNATIVE SYSTEMS**

#### **5.1 Halon 1211 Alternative Agents**

While the overall system performance will be the ultimate discriminator for system evaluation, the agent requirements can serve as a screen to eliminate those systems that cannot meet at least the minimum level of the required performance. The results from Part I - Development of Halon 1211 Alternatives of this study indicate that the only near term alternatives for Halon 1211 are those that are currently commercially available [Carpenter et al., 1997]. Results from Part II - Halon 1211 Requirements Review of this study demonstrate the need for a secondary agent(s) with Class A, 2-D and 3-D, Class B and Class C capabilities. For the majority of small fires, the collateral damage concerns are high. For these small fires, an agent is needed that limits the collateral damage. The terminology "clean agent" is avoided in this context in recognition of the potential use of PKP, historically considered a "dirty" agent. The corrosion and other collateral damage concerns for PKP need to be evaluated to determine its suitability in meeting the collateral damage requirements. PKP is recommended to be included in the list of

candidate agents until the collateral damage issues are resolved. The alternatives that are currently available that may meet the agent requirements are HFC-227ea, HFC-236fa, PKP and CO<sub>2</sub>.

## **5.2 Fire Fighting Systems**

The evaluation of Halon 1211 alternative systems against the operational requirements must consider the capabilities of other, co-located fire fighting systems. For example, the P-16 and TAU-2H may be viewed as serving a similar function to the flight line extinguisher with respect to providing larger quantities/capabilities of a secondary agent than the hand held extinguishers. However, unlike the flight line extinguisher, the P-16 and TAU-2H also contain internal supplies of AFFF for use in 2-D fires. In addition, AFFF hose lines are also immediately available on the flight deck. The flight line extinguisher must contain capabilities to extinguish 2-D fires (i.e., pool fires) based solely on the secondary agent while the 2-D fire capabilities of the P-16/P-25 and TAU-2H can be based on AFFF.

The co-located fire fighting systems are different on the flight line and the flight deck. The systems available to the maintenance staff and crew on the flight line are the flight line extinguisher (i.e., 150 pound, wheeled Halon 1211) and potentially hand held extinguishers. The systems available to the fire fighters on the flight line are hand helds, flight line extinguishers, CFR vehicles and potentially TAUs. The systems available to flight deck and hangar personnel are the hand helds, P-16 and/or TAU-2H. The systems available to shipboard damage control parties are hand helds, AFFF hose lines and the P-16 or TAU-2H. Each of these systems have different capabilities and are not suitable for all of the fire threats. These different system capabilities must be addressed in evaluating the effectiveness of each potential agent in each potential system. Combinations of these systems as fielded on the flight line and flight deck must provide the capabilities to meet all of the fire fighting requirements. Therefore, the evaluation of Halon 1211 alternative systems must be developed by including the combinations of all fire fighting systems that will be available on the flight deck and on the flight line. Table 1 provides the fire fighting systems that must be considered in the development and the evaluation of Halon 1211 alternative systems.

**Table 1. Fire Fighting Systems Currently Fielded on the Flight Line and the Flight Deck  
[NATOPS, 1994]**

<b>Fire Fighting Systems Available on the Flight Line</b>	
•	CO <sub>2</sub> , PKP and Halon 1211 hand held extinguishers
•	Halon 1211 wheeled (flight line) extinguishers
•	PKP/AFFF and Halon 1211/AFFF shore based TAUs
•	AFFF/Halon 1211 Crash, Fire and Rescue (CFR) vehicles
<b>Fire Fighting Systems Available on the Flight Deck</b>	
•	CO <sub>2</sub> , PKP and Halon 1211 hand held extinguishers
•	Halon 1211/AFFF TAU-2H
•	Halon 1211/AFFF P-16 (AFFF only when P-25 is fielded)
•	AFFF hose lines

### **5.3 Selection, Development and Optimization of Halon 1211 Alternative Systems**

Consistent with military acquisition policy, commercial off-the-shelf (COTS) systems will be considered for evaluation first. The COTS fire fighting systems are optimized to meet UL ratings or other criteria that may or may not be optimum for Naval aviation fire fighting. If direct COTS systems do not meet the requirements, modification of these systems will be considered. If modified COTS systems do not meet the requirements, developmental systems based on commercially available agents will be considered. For the modified COTS systems and the developmental systems, optimization of system parameters will be necessary in order to properly evaluate their potential in meeting the requirements. Variables such as agent quantity, flow rate, throw and dispersion patterns will need to be evaluated and included within the testing.

## **6.0 DEVELOPMENT OF FIRE TESTS**

The results from Part II - Halon 1211 Requirements Review of this study indicate the requirement to fight four "common" fire types: engine, wheel/brake, electrical and fuel spill (i.e., 2-D pool) [Verdonik et al., 7 January 1998]. The majority of these fires are small, but large fires may also result from these incidents. In addition, historical experience indicates that while large catastrophic events (i.e., Debris Pile) do not occur often, the ability to combat these fires is also a requirement.

For each of these five fire types, a specific test apparatus will be developed that accurately represents the threat encountered in the field. In order to ensure that the tests adequately depict the actual fire threat, each apparatus will need a base line for the two fire sizes considered in the development of the operational requirements, i.e., small and large. It is important to note, however, that there is no true distinction for a "small" fire versus a "large" fire. The size of the

fire is a continuum with a determination made between what is considered small or large based on a particular set of needs. Within this study the criterion has been based on the collateral damage concerns. A "large" fire is one where the damage due to the fire outweighs the potential damage from the agent. The remainder are considered "small" fires. While this is convenient from a conceptual approach, it does not provide a direct means to define a small fire based on the specific test parameters for each test apparatus.

One method to define the fire size and develop the base line is to perform rigorous analyses to develop the most probable fire size and severity for each fire type. The apparatus design and test parameters would be based lined solely upon the analyses. It is also possible to try to validate each apparatus using the current Halon 1211 systems. The apparatus design and test parameters would be altered until the results obtained with the current Halon 1211 systems were similar to those reported by the field in the fire incident data. It is important to make the distinction between validating each apparatus with the fielded Halon 1211 systems versus evaluating the effectiveness of an alternative agent and system against Halon 1211. Once a test apparatus is developed that represents the threat in the field, i.e., base lined, no further evaluation of candidate systems will be made against Halon 1211 systems. The pass/fail criteria will be based solely on the effectiveness against the fire threat simulated by the apparatus. The quantity of Halon 1211 and the effectiveness of Halon 1211 systems would not be used in the development of pass/fail criteria or in the evaluation of the effectiveness of Halon 1211 alternative systems.

It must be noted that a potential limitation exists with using the fire incident data to develop the validations based on the accuracy and statistical significance of the Halon 1211 quantities reported in the data. For example, the average quantity of Halon 1211 used for all fires in all equipment in the 1977-1991 fire incident data was 78 pounds versus 109 pounds used in the 1993 - 1995 fire incident data. These results were based on 176 and 201 incidents respectively. While it is recognized that the actual values for base lining would be those obtained for each Halon 1211 system for each type of fire, the significant difference in the average quantity suggests that the fire incident data may not provide enough accuracy. It will be necessary to analyze the two sets of fire incident data further to determine the quantity of Halon 1211 used by each system for each fire type. While it may appear easier to base line each apparatus using this validation, it may not provide accurate results if the quantities provided in the fire incident data do not depict actual field conditions or if there are not enough incidents available to provide statistical significance. It must also be noted that emissions of Halon 1211 resulting from such testing may be banned by the EPA in the near future. Preference will be placed initially on using the fire incident data to validate the base lining. If this method does not appear to provide accurate and/or statistically significant results or if the EPA bans the use of Halon 1211 for this purpose, the base lining will be based solely upon the rigorous analyses.

The base line threats simulated by the test apparatuses will be used to measure the ability of potential systems to meet the operational requirements. The majority of the testing will use specific pass/fail criteria such as complete extinguishment or a measured level of control of the fire depending upon the requirements for the fire type. Some test scenarios may only include

performance measures in order to develop doctrine and tactics, and to provide a measure of the capabilities and limitations of the systems.

## **7.0 HALON 1211 ALTERNATIVE SYSTEM TEST PLAN**

The competing requirements for developing and fielding new/modified fire fighting systems are the agent attributes, system effectiveness for the fire scenarios and the quantity of different types of systems to be fielded. It is not realistic from logistics, cost and training standpoints to field different agents and systems for each fire threat. The competing requirements must all be met through a minimum number of systems. The test plan will need to take into account these system constraints shipboard and shore side. For example, hand held extinguishers have historically been intended for small fires including the requirement to minimize collateral damage. However, based on the anticipated P-25 design that only includes a secondary agent in hand held extinguishers, these hand helds will also need to meet the 3-D requirements in combating a large Debris Pile fire that was formally met by the Halon 1211 within the P-16.

Based on the potential number of systems to be tested for each fire scenario, a systematic test regime and down-select process are needed in order to reduce the number of possible tests. The test sequence that is recommended is based on evaluating the performance of the smallest potential system first, i.e., the hand held extinguishers, to determine if they will meet the operational requirements for small fires and the 3-D requirements of the Debris Pile. If the smaller system cannot meet one or both of these requirements, the next larger system(s) will be tested, i.e., flight line extinguisher, shore based TAU and CFR vehicle for the flight line, and the P-16/P-25 and TAU-2H for the flight deck. While the test plan includes provisions to test all of the systems against all of the fire scenarios, it also provides for the earliest elimination of systems that cannot meet the operational requirements to reduce the number of tests required.

### **7.1 Engine Fire Tests**

Results from Part II - Halon 1211 Requirements Review of this study indicate that the predominant engine fire threat is from small fires due to wet starts, shut down of the engine and minor leaks [Verdonik et al., 7 January 1998]. These fires can be 2-D and 3-D. The agents and systems available to the flight line and flight deck personnel must be capable of extinguishing these small 2-D/3-D fires with minimal or no collateral damage. For large engine fires, the effectiveness in extinguishing the fire outweighs the collateral damage concerns. The agents and systems available to fire fighters must be effective against large 2-D and 3-D Class B fires. AFFF will meet the 2-D requirements. Halon 1211 alternative systems will need to provide the 3-D capabilities.

The engine test apparatus needs to adequately simulate the small 2-D and 3-D engine, APU and starter fires encountered in the field and allow for modification based on future systems. It is anticipated that large engine fires will be represented adequately by the Debris Pile discussed

later in this section. In order to accurately measure system performance, the apparatus should simulate actual conditions such as height and distance from personnel, clutter, obstacles and flight deck wind in addition to the fire parameters such as fire size and severity (e.g., quantity and flow rate of fuel and presence of heated surfaces). The apparatus should include capabilities to alter the parameters to determine the effectiveness of systems based on differing aircraft requirements including commercial aircraft.

Hand held extinguishers with an agent that causes no collateral damage will be tested first to determine which may meet the requirement to extinguish small engine fires. The tests may include the currently fielded CO<sub>2</sub>, PKP extinguishers, COTS HFC-227ea and HFC-236fa extinguishers and, based on the P-25 configuration, the currently fielded 20 pound Halon 1211 extinguisher. The use of 7-foot extensions, as provided for within the NATOPS, also needs to be included within the evaluation.

If hand holds (with an agent that does not cause collateral damage) cannot extinguish the small engine fire, they will not be considered further for any other small fire. In order to meet the small engine fire requirements in this case, a shore based system and shipboard system with increased extinguishment capability would be needed. The flight line extinguishers to be evaluated for the small engine fires would include COTS PKP and CO<sub>2</sub> systems, and developmental systems based HFC-227ea and HFC-236fa. It must be noted that a CO<sub>2</sub> system would not be acceptable on wheel/brake fires and may be eliminated from consideration for the flight line based on this requirement. Carbon dioxide systems may cause rapid cooling of the wheel assembly warned against in the NATOPS [NATOPS, 1994]. The shipboard systems that would need to be evaluated are the P-16/P-25 and the TAU-2H. The P-16 was originally designed to use PKP and some fielded shipboard TAUs currently use PKP. The original P-16, the currently fielded PKP TAUs and modifications to the P-16, P-25 and TAU-2H based on CO<sub>2</sub>, HFC-227ea and HFC-236fa would be considered for testing.

## **7.2 Debris Pile Fire Tests (2-D pool and 3-D cascade)**

While the results from Part II - Halon 1211 Requirements Review of this study did not indicate a large number of these events, historical experience has shown this to be a requirement [Verdonik et al., 7 January 1998]. The current Debris Pile scenario, i.e., 2-D pool and 3-D cascade fires with clutter, obstacles, shielded access and ordnance, was developed based on the USS NIMITZ fire. Although this fire type may exist for both small and large fires, the "small" Debris Pile fire scenario will be considered essentially the same as the small engine fire scenario. The main difference between the engine requirements and the Debris Pile requirements is collateral damage. In a Debris Pile scenario, there is little concern for collateral damage. The agents and systems available to the fire fighters must be capable of extinguishing the 2-D and 3-D fire in the presence of shielding and obstacles, without allowing for cook-off of ordnance.

For the small 2-D and 3-D fires, the engine test apparatus will be considered sufficient to simulate the threat. For the large 2-D and 3-D fires, it is anticipated that the standard Debris Pile

will be used. The apparatus will include instrumented ordnance (thermocouples), cross and head winds, and may also include radiometers for fire repeatability. It must be noted that there is currently an international effort to develop a standard 3-D test apparatus for use in evaluating aviation fire fighting agents and systems. Consideration should be given to including this new test apparatus in the testing.

While the Debris Pile was originally developed against a shipboard event, the requirement for a similar shore side event also exists. The AFFF from shipboard hose lines, P-16/P-25 and TAU-2Hs, and shore side TAUs and CFR vehicles will meet the 2-D Class B and ordnance cooling requirements. To account for the current P-25 configuration, the currently fielded PKP, CO, and 20 pound Halon 1211 hand held extinguishers and the COTS HFC-227ea and HFC-236fa extinguishers used in conjunction with AFFF need to be tested to determine if they will extinguish the Debris Pile fire. The tests will allow the use of more than one hand held used either simultaneously or in series to meet this requirement.

If the hand holds/AFFF cannot extinguish the Debris Pile fire, the P-16, P-25, TAU-2H and at least one flight line system must contain a secondary agent for the 3-D fire. The need for this secondary agent to minimize collateral damage will depend upon the results for the hand held extinguishers in all of the small fire tests. If the hand held extinguishers with an agent that minimizes collateral damage cannot extinguish the small fires, these systems will need a secondary agent that minimizes collateral damage. Depending upon the results for hand holds, the flight line systems to be considered are (1) the COTS PKP and developmental flight line extinguishers based on HFC-227ea and HFC-236fa, (2) the currently fielded PKP shore based TAU and developmental shore based TAUs based on HFC-227ea and HFC-236fa and (3) internal supplies of PKP, HFC-227ea and HFC-236fa in the CFR vehicle.

The requirements for the flight deck are different than for the flight line. The need for a secondary agent and a secondary agent that minimizes collateral damage will be based only on the results of the hand holds in extinguishing the small engine, electrical and spill fires. The lack of the wheel/brake fire also allows CO<sub>2</sub> to be considered in meeting the secondary agent requirements. If the hand held extinguishers with an agent that minimizes collateral damage cannot extinguish the small fires, these systems will need a secondary agent that minimizes collateral damage. The systems to be considered are the original P-16 design, currently fielded PKP shipboard TAUs, and developmental systems for the P-16, P-25 and TAU-2H based on CO<sub>2</sub>, HFC-227ea and HFC-236fa.

### **7.3 Wheel/brake Fire Tests (Flight Line Only)**

Results from Part II – Halon 1211 Requirements Review of this study indicate that wheel/brake fires are either easily extinguished with the current hand holds and flight line extinguishers or require significant cooling to extinguish the fire [Verdonik et al., 7 January 1998]. The agents and systems available to the flight line personnel must be able to extinguish small 2-D and 3-D Class B and Class A fires until the fire department responds. Extinguishers

that provide better cooling of the wheel/brake assembly would increase the capability in meeting this threat. For the larger fires, the requirement exists for an effective cooling agent. Water and AFFF on the CFR vehicle and shore based TAU meet this requirement. The need for large internal supplies of a secondary agent on the CFR vehicle and TAU to fight wheel/brake fires is not apparent from the fire incident data.

Wheel/brake fires are caused by the build up of heat in the wheel/brake assembly igniting wheel grease and hydraulic fluids (Class B) and may involve the tire (Class A). The apparatus should simulate the actual conditions by heating the assembly until the wheel grease and/or the 3-D hydraulic fluid spray ignite. Another important condition is the pre-burn time so that the tire may also become involved in the fire. Other parameters such as the wheel and brake materials and the type of Class B fuels also need to be considered to simulate actual fire scenarios.

With the exception of CO<sub>2</sub>, the hand held extinguishers that passed the small engine fire would be evaluated first in the small wheel/brake fire. Carbon dioxide is not an acceptable agent on wheel/brake fires. The hand holds that would be considered are the currently fielded PKP, the COTS HFC-227ea and HFC-236fa extinguishers.

The hand held extinguishers that meet the small wheel/brake fire would be tested for control of the larger wheel/brake fire until the fire department deploys. If the hand holds cannot control the larger wheel/brake fire, the flight line extinguisher would be needed to meet this threat. If hand holds cannot extinguish the small wheel/brake fire, the flight line extinguisher with an agent that does not cause collateral damage would be needed to meet both wheel/brake fire threats. Commercially available flight line extinguishers with PKP and developmental systems based on HFC-227ea and HFC-236fa need to be considered. In recognition of the availability of AFFF/water in the shore based TAUs and CFR vehicles, and fans for use in cooling the hot wheel/brake assembly, testing of large quantities of secondary agents (i.e., in the TAU and CFR vehicle) for wheel/brake fires does not appear to be required.

#### **7.4 Electrical Fire Tests**

Results from Part II - Halon 1211 Requirements Review of this study indicate that the predominant electrical fire threat is small fires involving Class A materials. In some cases, electrical fires may also involve Class B fuels, e.g., the fuel is used as a heat sink for avionics cooling. The agents and systems available to the flight line and flight deck personnel must be capable of extinguishing small electrical fires with minimal or no collateral damage. For large electrical fires, the effectiveness in extinguishing the fire outweighs the collateral damage concerns. The agents and systems available to fire fighters must be effective against large Class A and 2-D and 3-D Class B fires.

The electrical fire apparatus needs to adequately simulate small and large energized electronics/avionics fires with Class A and Class B materials and allow for modification based on future systems. In addition to the fire size and severity, the apparatus should simulate other actual

conditions such as clutter, obstructions, volume, types of Class A materials and quantity of Class B materials. The apparatus should include capabilities to alter these parameters to determine the effectiveness of systems based on differing aircraft requirements

The hand held extinguishers that successfully extinguished the small wheel/brake fire will be tested first against the small electrical fire. The tests will also include the hand helds that did not successfully extinguish the small wheel/brake fires, including CO<sub>2</sub>, but were successful in the small engine fire for potential use on the flight deck.

If hand helds with an agent that does not cause collateral damage cannot extinguish the small electrical fire, they will be ruled out of consideration for all small fires. In order to meet the small electrical fire in this case the flight line extinguisher, P-16, P-25 and TAU-2H would need an agent that does not cause collateral damage. The shore side systems to be considered are COTS PKP and developmental systems with HFC-227ea and HFC-236fa. The shipboard systems to be considered are the original P-16 design, fielded PKP TAUs and the developmental systems with CO<sub>2</sub>, HFC-227ea and HFC-236fa.

For large electrical fires, the need to limit collateral damage is out weighed by the need to extinguish the fire as quickly as possible [Verdonik et al., 7 January 1998]. AFFF would be expected to meet most of this requirement except for the 3-D portion. Analogous to the Debris Pile, it may be possible that hand helds can provide the 3-D capabilities. If the hand helds/AFFF cannot extinguish the large electrical fire, the flight line extinguisher used in conjunction with AFFF, and the P-16, P-25 and TAU-2H would need to be tested. The systems to be considered are the same that would be considered for the Debris Pile testing previously described.

## **7.5 Spill Fire Tests (2-D Pool Fire)**

Results from Part II - Halon 1211 Requirements Review of this study indicate that small spill fires are much more predominant than large spill fires [Verdonik et al., 7 January 1998]. For both small and large spill fires, the collateral damage concerns are expected to be minimal. However, due to the higher aircraft density and the presence of winds on the flight deck, the collateral damage concerns in extinguishing these fires may be somewhat higher on the flight deck than on the flight line. The agents and systems available to the flight line and flight deck personnel must be capable of extinguishing small 2-D pool fires and controlling larger ones until the fire fighters respond. The systems and agents available to fire fighters would need to be capable of extinguishing large spill fires. Based on the availability of AFFF for large spill fires, no requirement exists for large quantities of a secondary agent to combat 2-D spill fires.

The spill fire test apparatus needs to simulate small and "medium" size spills on the flight line and the flight deck allowing the fuel to spread over a fairly level concrete/asphalt or metal surface with built-in pockets to allow "deep" pooling. For the flight deck, the presence of wind should also be incorporated to evaluate the extinguishment capabilities and the potential for causing collateral damage by carrying the agent to nearby aircraft. The fuel may also be heated

indicative of its use as a heat sink in some aircraft. This apparatus will not equate to the UL pan fire tests.

For the flight deck, the presence of AFFF from the P-16, P-25, TAU-2H and hose lines likely eliminates the 2-D requirement for the secondary agent for both small and large 2-D fires. Performance data for hand held extinguishers and, if needed, the secondary agent from the P-16, P-25 and TAU-2H should be developed for the small and larger pool fires to provide information for doctrine and tactics. The systems to be tested are those that pass the small engine and electrical fires and the Debris Pile fire requirements.

For the flight line, the secondary agent in the hand helds and/or the flight line extinguisher is the only agent immediately available to combat the small spill fire and to control larger spill fires until the fire department deploys. The systems to be tested are those that successfully met the small engine, wheel/brake and electrical fires and Debris Pile requirements.

## **8.0 SUMMARY OF TEST PLAN BY SYSTEM**

### **8.1 Hand Held Extinguishers**

Hand held systems need to be evaluated for three separate requirements:

(1) extinguishment of the small fires, control of the larger wheel/brake and spill fires and the ability to provide the entirety of the 3-D requirements. The operational requirements needed for the small fires are (1) causes little or no collateral damage and (2) on the flight line extinguishes the small engine, electrical, spill and wheel/brake fires or for the flight deck extinguishes the small engine and electrical fires. For the 3-D capabilities, the operational requirement is to extinguish the Debris Pile fire with the appropriate AFFF system. The systems to be considered are the currently fielded CO<sub>2</sub> (flight deck only), PKP and 20 pound Halon 1211 extinguishers and the COTS HFC-227ea and HFC-236fa extinguishers.

While the test matrix includes provisions to test all of the hand helds against all of the small fires and the full size Debris Pile, the down-select process may eliminate some of this testing. The following outlines the hand held extinguisher test sequence and the down-select process.

- A "paper" assessment of the collateral damage issues for PKP will be undertaken. Based on this assessment, PKP systems may be eliminated from consideration for the small engine, wheel/brake and electrical fires due to the collateral damage requirements.
- Hand helds will be tested first against the small engine fires. Only those that pass the small engine fire test will be considered for further evaluation against the remainder of the small fires.

- Hand holds will be tested second against the Debris Pile. If no hand held extinguisher can meet the small engine fire or provide the entire 3-D requirement, all hand holds will be eliminated from further testing.
- The hand holds that passed the small engine fire will be tested against the small wheel/brake fire. Only those that passed the small wheel/brake fire will be considered further as the primary system for the flight line.
- For the flight deck, the hand holds that passed the small engine fire and for the flight line the hand holds that passed the small wheel/brake fire will be tested against the small electrical fire.
- Since hand holds may not be needed to extinguish small spill fires on the flight deck due to the availability of AFFF, extinguishment of the small engine and electrical fires may be considered sufficient in meeting the operational requirements. Larger flight deck systems would not be required to contain a secondary agent that does not cause collateral damage.
- For the flight line, the hand holds that passed the small electrical fire will be tested against the small spill fire. Hand holds that pass the small spill fire would meet the operational requirements for the flight line. Larger flight deck systems would not be required to contain a secondary agent that does not cause collateral damage.

## **8.2 Flight Line Extinguisher and Shore based TAU**

Depending upon the results for the hand holds, the flight line extinguisher may need an agent that minimizes collateral damage and/or may need to supply the 3-D agent requirements. The operational requirements for the flight line extinguisher and shore based TAU will depend upon the results of hand held extinguishers.

- If hand held extinguishers meet the small fire requirements, 3-D requirements, and adequately control the larger spill and wheel/brake fires, flight line extinguishers and TAUs would not be required.
- If hand holds meet the small fire requirements and Debris Pile 3-D requirements, but do not adequately control the larger spill and wheel/brake fires, the operational requirements for flight line extinguishers would be to control the larger wheel/brake and spill fires for a time period considered sufficient for the fire department to respond in a system constrained to a size suitable for first response use. For this case, there is no concern for limiting collateral damage. Systems to be considered are the COTS PKP and developmental systems with HFC-227ea and HFC-236fa.
- If the hand holds meet the 3-D requirements but cannot meet the requirements for small fires, the operational requirements for the flight line extinguisher would be to cause little or no collateral damage, extinguish small engine, electrical, spill and wheel/brake fires, and

control larger spill and wheel/brake fires in a system constrained to a size suitable for first response use. Systems to be considered are the COTS PKP and developmental systems with HFC-227ea and HFC-236fa.

- If the hand helds meet the small fire requirements but cannot meet the 3-D requirements, the operational requirements for the shore based TAU would be to extinguish the Debris Pile fire allowing the use of AFFF from additional sources. Depending upon the availability of the shore based TAUs, the flight line extinguisher may also need to have the same operational requirement and be of the appropriate size for first response use. Systems to be considered are the COTS PKP and developmental systems with HFC-227ea and HFC-236fa.
- If hand helds cannot meet either the small fire requirements or the 3-D requirement, the operational requirement for the flight line extinguishers would be to cause little or no collateral damage, extinguish small engine, electrical, spill and wheel/brake fires, control larger spill and wheel/brake fires, and depending upon the availability of shore based TAUs, extinguish the Debris Pile fire in conjunction with AFFF within a system constrained to a size suitable for first response use. The operational requirement for the shore based TAU would be to extinguish the Debris Pile allowing the use of AFFF from other sources. Systems to be considered are the COTS PKP and developmental systems with HFC-227ea and HFC-236fa.

As was the case for the hand held extinguishers, PKP may be eliminated from consideration as an agent that does not cause collateral damage. Somewhat different than the case for hand helds, the size of these systems will be a variable within the testing. Therefore, it will be important to try to begin the testing with the fire tests that will require the most agent. It is anticipated that the same test sequence as previously described for hand helds would also be used for the flight line extinguisher. The test sequence may change based on any lessons learned from the hand held testing with respect to the fire threat that the most difficult to extinguish. It is currently anticipated that the overall test sequence would be as follows: small engine, Debris Pile, small wheel/brake, larger wheel/brake, small electrical, small spill and larger spill. Regardless of the actual test sequence a similar down-select/elimination process as developed for the hand held extinguishers would also be used.

### **8.3 P-16, P-25 and TAU-2H**

Analogous to the flight line extinguisher and shore based TAU, the operational requirements for the P-16, P-25 and TAU-2H will depend upon the results of hand held extinguishers.

- If hand held extinguishers meet the small fire requirements and the 3-D requirements, the secondary agent may be removed from the P-16 and the TAU-2H. Due to the presence of AFFF hose lines, these systems would not be required on the hangar deck.

- If the hand helds meet the 3-D requirements but cannot meet the requirements for small fires, the operational requirements for the P-16, P-25 and TAU-2H would be to cause little or no collateral damage and extinguish small engine, electrical and spill fires. Systems to be considered are the COTS PKP, original P-16 design and modifications to the P-25 based on the original P-16 design.
- If the hand helds meet the small fire requirements but cannot meet the 3-D requirements, the operational requirements for the P-16, P-25 and TAU-2H would be to extinguish the Debris Pile fire. Systems to be considered are the currently fielded PKP TAUs, original P-16 PKP design, modifications to the P-25 based on the original P-16 design and developmental systems based on CO<sub>2</sub>, HFC-227ea and HFC-236fa.
- If hand helds cannot meet either the small fire requirements or the 3-D requirement the operational requirement for the P-16, P-25 and TAU-2H would be to cause little or no collateral damage and extinguish small engine, electrical and spill fires. Systems to be considered are the currently fielded PKP TAUs, original P-16 PKP design, modifications to the P-25 based on the original P-16 design and developmental systems based on CO<sub>2</sub>, HFC-227ea and HFC-236fa.

The comments on the potential elimination of PKP previously described for the hand held and flight line extinguishers are also applicable for the flight deck systems. In addition, the NATOPS will allow a towed TAU-2H to be considered as an acceptable alternative to the P-16 for some ships [NATOPS, 1996]. The TAU-2H is a smaller system than the P-16 with respect to agent quantities. In order to reduce the potential retrofit costs, it will be important to incorporate the space constraint into the test plan. While it is not the objective to find a drop-in agent to replace Halon 1211 that performs exactly the same as Halon 1211, it would be a major economic advantage for these flight deck systems for the alternative agent to use the same or less space than is currently used by the Halon 1211. Therefore, the initial systems to be tested will be constrained to the space available within the TAU-2H. If a system with this size constraint cannot be developed that meets the operational requirements, the system size of the P-16 will be considered next. If systems with the P-16 size constraint cannot be developed that meet the operational requirements, systems constrained to what may fit into the P-25 will then be considered.

It is anticipated that the same fire test sequence as previously described for hand helds would be used for the larger flight deck systems. The test sequence may change based on any lessons learned with respect to the fire threat that is the most difficult to extinguish from the testing of hand helds, flight line extinguisher and/or shore based TAU. It is currently anticipated that the overall flight deck test sequence would be as follows: small engine, Debris Pile, small electrical, small spill and larger spill. Regardless of the actual test sequence a down-select/elimination process similar to that developed for the hand held extinguishers would be used that also incorporates the size constraints for these systems.

## **8.4 CFR Vehicle Systems**

Depending upon the results for the shore based TAU and the flight line extinguisher and the availability of the shore based TAU, a secondary agent may be required on the CFR vehicle for the large catastrophic events. The operational requirement would be to extinguish the Debris Pile fire. No collateral damage concerns exist with the agent; therefore, it is anticipated that PKP would meet this requirement. While it does not currently appear necessary, other agents such as HFC-227ea, HFC-236fa and CO<sub>2</sub> could also be considered for testing. In addition, AFFF application methods such as the COTS AFFF/PKP combination streaming method/system may also be considered for testing.

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